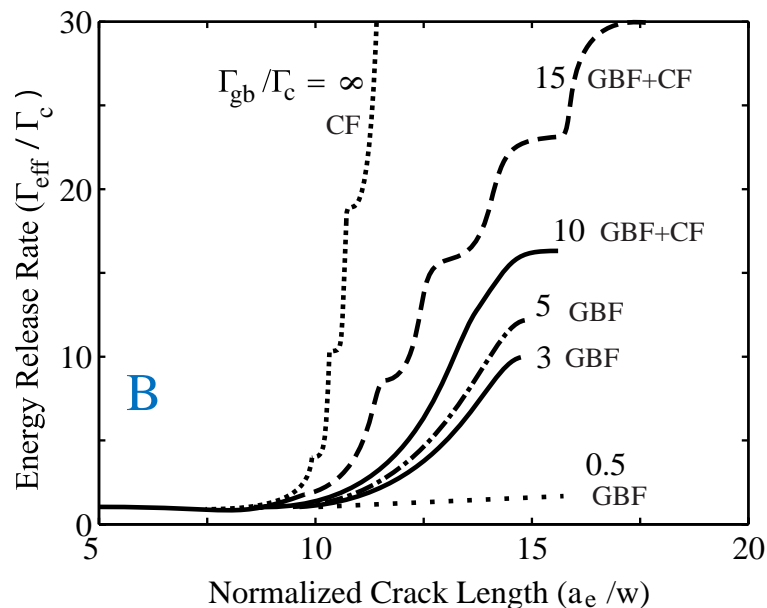
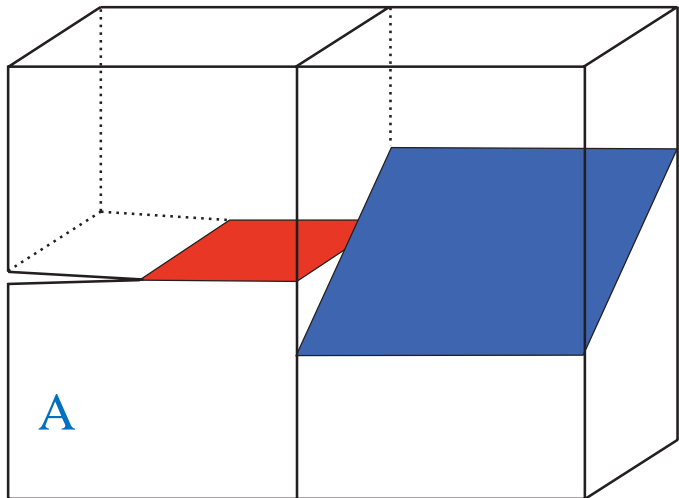




# Mechanics of crack deflection at a twist grain boundary

Yujie Wei, Allan F. Bower, Huajian Gao

Sponsored by the National Science Foundation's Materials Research Science & Engineering Program on "Micro-and Nano Mechanics of Electronics and Structural Materials" at Brown University, Providence, RI 02912



Heterogeneous brittle solids such as ceramics, lamellar intermetallics, and polycrystalline hexagonal-close-packed (hcp) metals such as Zr, Zn and Cd are technologically important and broadly used. Zirconium, for example, has a low absorption cross section for neutrons, and is therefore used in nuclear energy applications. Titanium aluminide (TiAl) is a candidate material for many structural applications, and TiAl alloys have the potential to replace nickel-based superalloys in some sections of jet engines. The most common mode of failure in all these materials is cleavage cracking along weak planes or interfaces in the solid. The low fracture toughness associated with cleavage cracking is a major concern in practical applications, and there is currently great interest in finding ways to optimize their microstructure so as to make them resistant to fracture.

In this project, the fracture toughening mechanism by twisted grain boundaries (GBs) are investigated. Fig. A shows the diagram of two grains adjoined by a twisted GB. As a crack front propagates to the GB, it may (a) deflect along the GB, and (b) penetrate into the second grain by initiate multiple cleavage cracks with certain space between each one. This work reveals the interaction of GB fracture (GBF) and cleavage fracture (CF) at several twisted angles and different toughness ratio in the GB ( $\Gamma_{gb}$ ) and in cleavage planes ( $\Gamma_0$ ).

Our investigation predicts (i) a critical toughness ratio between the GB and the cleavage planes for the crack to propagate into the adjacent grain; (ii) an array of cracks in the GB and the twisted grain; (iii) the macroscopic mode I toughness of the solid as a function of crack length; and (iv) the influence of GB toughness and twist misorientation on the effective toughness of the solid ( $\Gamma_{eff}/\Gamma_{ef}$ ). Fig. B gives then normalized effective toughness versus effective crack length ( $a_e/w$ ) for a crack crossing a 14 degree twist GB, for several values of normalized GB strength. If the GB strength is infinite, the effective toughness is unbounded.